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A review on energy scenario and sustainable energy in Malaysia

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ABSTRACT

Abundant and economical energy is the life blood of modern civilizations. Global energy consumption in 2009 is expected to slightly increase to about 11428.1 Mtoe and around 88% are from fossil fuels. Fossil fuel will become rare and a serious shortage in the near future has triggered the awareness to find alternative energy as their sustainable energy sources. Development and economic growth continue to affect the growing demand of energy consumption in Malaysia. The crucial challenge faced by power sector in Malaysia currently is the issue of sustainability. This study discusses the current energy scenario and explores the alternative energy like biomass, solar, wind and mini-hydro energy to ensure reliability and security of energy supply in this country. It is found that, total hydropower resources and potential hydropower is 29,000 MW out of which only 2,091 MW is utilized. On the other hand, Malaysia has the potential to be one of the major contributors of renewable energy in palm oil biomass and become a role model to other countries in the world that has huge biomass feedstock. As a final note, to make the fuel mix for 2020 secure and environmentally sustainable, Malaysia must strive to increase its efforts in attaining greater efficiency in energy conversion, transmission and utilization.

Contents

1. Introduction

The global energy consumption is likely to grow faster than the increase in the population. The fuel consumption was growing from 6,630 million tons of oil equivalent (Mtoe) in 1980 to almost double of the energy consumption which had reach 11,295 Mtoe in 2008 as shown in Table 1 [1]. According to the estimation done by International Energy Agency, a 53% increase in global energy consumption is foreseen by 2030. The energy consumption is mainly based on fossil fuels which account for 88.1% whereby with crude oil consisting of 34.8%, coal 29.2% and natural gas 24.1%. However the share of nuclear energy and hydroelectricity are very small with only 5.5% and 6.4% respectively. At current production rates, global proven reserves for crude oil and natural gas are estimated to last for 41.8 and 60.3 years respectively. Furthermore, the fossil fuels will significantly contribute to the emission of

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Table 1
Global primary energy consumption [1].

Source	1980		2008	
	Mtoe	Share (%)	Mtoe	Share (%)
Petroleum	2,979.8	44.9	3,927.9	34.8
Coal	1,807.9	27.3	3,303.7	29.2
Natural gas	1,296.8	19.6	2,726.1	24.1
Nuclear	161.0	2.4	619.7	5.5
Hydropower	384.3	5.8	717.5	6.4
Total	6,629.8	100.0	11,294.9	100.0

greenhouse gases (GHG) from the combustion and raising the climate change issue. Thus, the new and renewable energies will become one of the main energy sources for the world. Currently, renewable energy contributes only 11% of the total global energy used [2].

The energy generates from the combustion of fossil fuels has simultaneously created several environmental concerns which can threaten the sustainability of our ecosystem. One of the primary concerns will be the emissions of greenhouse gases and other types of air pollutants such as hydrocarbons, nitrogen oxide and volatile organic compounds [3]. The major contributor of the greenhouse gas is carbon dioxide emissions and the trend has been increasing every year since 1982 as shown in Fig. 1 [1]. It is shown that the global carbon dioxide emission has risen significantly from 19,380 million tons in 1980 to 31,577 million tons in 2008. It is predicted that carbon dioxide emission will increase to 40 billion tons in year 2030 if no tremendous effort are thrown in to mitigate it [4]. It is inevitable that CO_2 emission will continue to climb as long as fossil fuels remain as the main contributor in the energy mix. Huge accumulation of those gases in our atmosphere will eventually lead to drastic climate changes, acid rain and smog.

The crucial challenge facing the power sector in Malaysia currently is the issue of sustainability. This sector is important to ensure the security as well as reliability of energy supply and the diversification of the various energy resources. Therefore, this paper presents an overview of the current energy scenario in term of primary energy demand, supply and reserves in Malaysia. The security and sustainability of future energy in various renewable energy options like biomass, wind, solar and hydro power has also been explored. Besides, the most recent alternative energy scenario and implementation in Malaysia has covered in this study.

2. Malaysia energy scenario

Malaysia is a population with about 27.73 million, covering an area of 329,750 km^2 based on the latest census in 2008. The GDP grew at an average rate over 5.7% in Malaysia during the last 6 years. As such, being a fast industrializing country, it is expected that electricity demand will continue to rise and keep to the same trend with GDP growth. Like many developing countries, development and economic growth continue to affect the growing of energy consumption demand in the nation. Total primary energy supply had increased steadily over the past 18 years. It is estimated to reach about 64 Mtoe in 2008 which is more than 200% increase from 1990 as shown in Fig. 2. This is considered relatively high among developing countries. Apart from that, the number of final energy consumption has also increased drastically due to rapid urbanization and industrialization. Hence, the final fuel consumption has risen at an annual growth rate of 7.2% from 1990 to 2008 and reached 44.9Mtoe in 2008. Fig. 3 shows the final energy consumption by sector from 1990 to 2008 in Malaysia. It also indicates that industrial sector is the major energy consumption with a record of 19.1Mtoe in 2008 and followed closely by transportation sector which is mostly powered by petroleum products [5]. With future energy demand expected to grow at an annual growth rate of 5–7.9% for the next 20 years, energy security is becoming a serious issue as fossil fuels are non-renewable energy and will deplete eventually in near future.

Malaysian energy sector was highly dependent only on a single source of energy – crude oil before 1980. The four fuel diversification policy was introduced and implemented in Malaysia after the occurrence of two international oil crisis and quantum leaps in prices in the year 1973 and 1979 [6]. Faced with the possibility of prolonged energy crisis, the government called for the diversification of energy resources other than crude oil. The fuel diversification strategy was incorporated into the Malaysian National Energy Policy in order to achieve a more balanced consumption [7]. The alternative energy resources available at that time were hydropower, natural gas and coal as there were large untapped indigenous hydropower and natural gas reserves, while

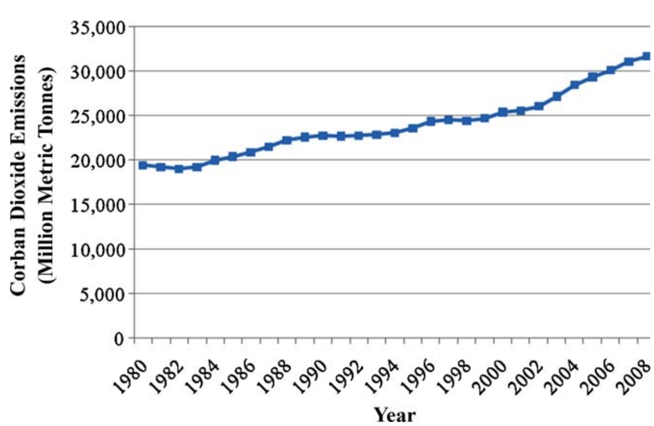

Fig. 1. Global total carbon dioxide emission from year 1980 to 2008.

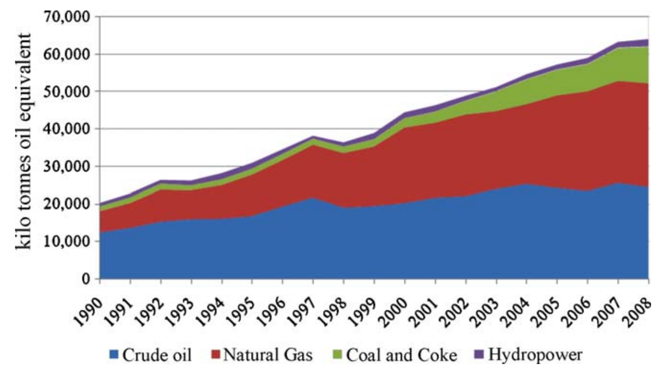

Fig. 2. Primary energy supply by fuel type in Malaysia [5].

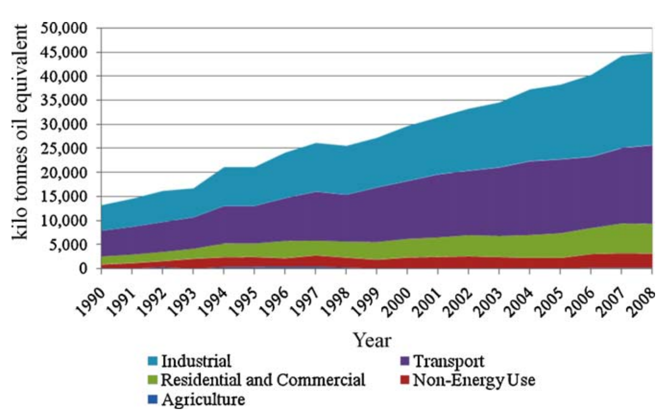

Fig. 3. Final energy consumption by sector in Malaysia [5].

Table 2
Primary energy supply share in Malaysia [5].

Primary energy supply	Amount (ktoe)		Share (%)	
	1990	2008	1990	2008
Crude oil	12,434	24,494	61.1	38.2
Natural gas	5,690	27,800	27.9	43.4
Coal and coke	1,326	9,782	6.5	15.3
Hydropower	915	1,964	4.5	3.1
Total	20,365	64,040	100	100

coal was considered an abundant worldwide resource with a very low and stable price [8]. Table 2 shows that the contribution of crude oil in energy supply dropped from 61.1% in 1990 to 38.2% in 2008 after the implementation of fuel diversification strategy. On the other hand, natural gas has become the main contributor of final energy consumption with 43.4% of total energy supply in 2008. The primary energy supply were natural gas 43.4%; crude oil 38.2%; coal 15.3% and hydropower 3.1% in 2008. Crude oil is no longer seen as a feasible source of energy supply in Malaysia due to its fast depleting supply. Nowadays, crude oil is mainly used as a backup supply for emergency [9]. Crude oil and natural gas still dominated the energy supply in Malaysia and are expected to continue to play a major role in primary energy mix. However, the burning fossil fuel like crude oil and natural gas may totally exhaust in one day. Besides, it will raise the climate change issue and significantly contributes to greenhouse gas emissions. Both of these issues are of major global environmental concerns that will have disastrous impact on the socio-economic development in Malaysia.

3. Energy mix in Malaysia

Malaysia is currently adopting the Five-Fuel Diversification Strategy energy mix implemented in the year 1999. According to this strategy, the energy mix in Malaysia is contributed by five main sources, namely natural gas, coal, oil, hydro and renewable energy. Besides, Malaysian government launched the Small Renewable Energy Power Programme (SREP) in 2001. This programme was the first step to encourage and intensify the utilisation of renewable energy in power generation.

3.1. Natural gas

Natural gas has become an increasingly valuable resource and a global commodity. Therefore, the demand for natural gas has significantly increased. In Malaysia, natural gas has become the main energy contributor since early 20 s. The volume of natural gas reserve is 2.49 trillion meter cubic in 2008 and most of the natural gas production comes from East Malaysia, especially offshore Sarawak [5]. The production of natural gas has risen steadily in recent years and reaching 198 million meter cubic per day in 2008 which is an increase of 22% since year 2002. Besides, domestic natural gas consumption has also increased substantially with 941.6 billion meter cubic in 2008. Natural gas reserve in Malaysia is the largest in South East Asia and 12th largest in the world. There are three LNG processing plants in Malaysia, all located in a massive complex at Bintulu (East Malaysia-Sarawak) and supplied by the offshore natural gas fields at Sarawak. The Bintulu facility is the largest LNG complex in the world, with a total liquefaction capacity of 31 billion meter cubic or 22.7 million metric tons per year [9]. The natural gas consumption increases drastically from 2.5 million tons in 1990 to around 25 million tons in 2008 after Malaysia implemented fuel diversification strategy. Power station sector is the major contribution which account for half of the total natural gas consumption, followed by industrial sector as shown in Fig. 4.

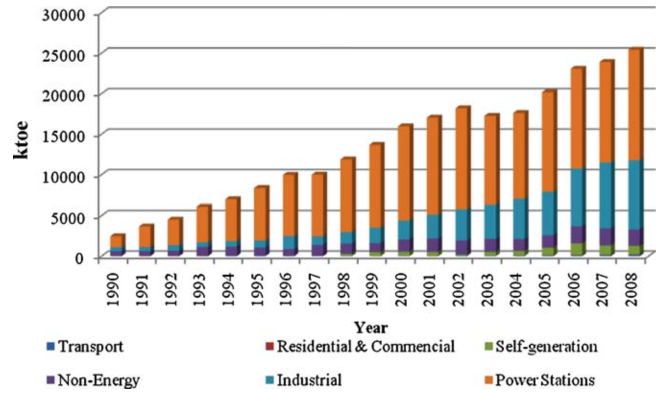

Fig. 4. Natural gas consumption by sector [5].

3.2. Crude oil

The depleting reserves and high price for crude oil have significant effect on the role of oil in the energy mix. The contribution of oil in the energy mix was once up to 90% in 1980 and has declined sharply after fuel diversification strategy was implemented in 1981. After the international oil crisis in 1973 and 1979, the government had called for the diversification of energy resources to prevent over-dependency on oil. In 2008, Malaysia has proven oil reserves of 5.46 billion barrels and 68% are located in east Malaysia Sabah and Sarawak [5]. Malaysia's oil production has declined in recent years and the average oil production is around 690 thousand barrels per day in 2008 with 564 thousand barrels crude oil and 126 thousand barrels condensates oil. When the production rate is consistent at around 700 thousand barrels per day, the ratio between reserve and production of 21 indicated that Malaysia's oil reserves will be exhausted in next 21 years.

There are five active oil refinery facilities in Malaysia with a total production of 592 thousand barrels per day as shown in Table 3. The largest refinery capacity is 155 thousand barrels per day in Port Dickson, Negeri Sembilan by SHELL Refining Co. (FOM) Bhd. Malaysia's state-owned national oil company, Petroleam Nasional Berhad (PETRONAS) which dominates the upstream and downstream activities of the country's oil sector. PETRONAS operates three refineries (249,000 bbl/d total capacity), while Shell (155,000 bbl/d) and ExxonMobil (88,000 bbl/d) operate one plant respectively. Malaysia has invested heavily in refining activities during the last two decades and is able to meet the country's demand for petroleum products domestically, after relying on the refining industry in Singapore for many years.

3.3. Coal

Being the cheapest and most abundant available fossil fuel, coal will always have a role in the energy mix in certain countries like USA and China, where coal is the main source of fuel. On the other hand, coal in Malaysia only contributes about 8.8% to the energy mix in 2000 and there is only increase in demand in recent year [6]. The total production of coal has accumulated to 1.17 million tons in 2008 and the primarily production comes from the mines in Sarawak. Moreover, Malaysia has huge coal reserves located in the states of Selangor, Sarawak and Sabah. Total coal reserves are 1938.4 million tons of various kinds ranging from lignite to anthracite as show in Table 4. The coal reserve can further divided into 280.8 million tons in measured, 378.2 million tons indicated and the balance of 1279.3 million tons is inferred. There are more

Table 3
Refinery licensed capacity [5].

Oil company	Location	Start up date	Thousand barrels/day
SHELL Refining Co. (FOM) Bhd	Port Dickson, Negeri Sembilan	1963	155
ESSO Malaysia Bhd	Port Dickson, Negeri Sembilan	1960	88
PETRONAS	Kertih, Terengganu	1983	49
PETRONAS	Melaka	1994	100
Malaysia Refining Company Sdn Bhd (PETRONAS/ConocoPhillips)	Melaka	1998	100

Table 4
Production and reserves of coal in Malaysia.

Location	Reserves (Million tons)			Production (ktons)	Coal type
	Measured	Indicated	Inferred		
Sarawak					
1. Abok, Sri Aman	7.3	10.6	32.4	168.0	Coking coal, semi-anthracite
2. Kapit & Mukah	262.7	312.4	916.7	999.0	Sub-bituminous
3. Bintulu	6.0	–	14.0		Hydrous lignite
Sabah					
1. Silimpopon	4.8	14.1	7.7		Sub-bituminous
2. Labuan	–	–	8.9		Sub-bituminous
3. Maliau	–	–	215.0		Bituminous
4. Meliabau	–	17.9	25.0		
5. South West Malibau	–	23.2	–		
6. Pinangan West Middle Block	–	–	42.6		Bituminous
Selangor					
1. Batu Arang	–	–	17.0		Sub-bituminous
Total	280.8	378.2	1,279.3		
Grand total	1,938.4			1,167.0	

than 80% of the coal reserves are located in Sarawak, 18.5% in Sabah and only 1.5% in Peninsular Malaysia. Generally, the coal reserves in Malaysia have heat values ranging between 21,000 kJ/kg and 30,000 kJ/kg with low ash and sulfur levels. The largest reserves of coal are located in Kapit & Mukah, Sarawak and in Maliau, Sabah.

Malaysia's demand for coal has been on the rise, with 15 million tons in 2008 and is expected to rise to 19 million tons by 2010. Most of the country's requirements are met by imports from Indonesia, Australia and China [9]. They are consumed mainly by the power generation and industrial sector like cement plants, iron and steel plants. Most of the coal is imported but efforts are continuing to enhance the security of supply by exploring the potential for development of local sources particularly in Sarawak, as well as securing long-term supplies from abroad. There are four coal fired plants to which Malaysia's state-owned power company and Tenaga Nasional Berhad (TNB) arrange the coal supplies. TNB owns two of the plants, there are Kapar (1600 MW) and Janamanjung (2100 MW) plants. Two others are independent power producers (IPPs), namely Tanjong Bin (2100 MW) and Jimah (1400 MW).

3.4. Hydropower

Hydropower is the only renewable energy technology that is commercially viable on a large scale in Malaysia. Moreover, hydropower dams can and have made important and significant contributions to human development. Firstly, it is a renewable energy source and produces negligible amounts of greenhouse gases. In long term, it stores large amounts of electricity at low cost and it can be adjusted to meet consumer demand. Furthermore, hydro dams are multipurpose and are built primarily for social–economic development like irrigation, water supply, flood control, electric power and improvement of navigation. In the last two centuries, hydropower has also played a key role in producing large-scale power and electricity [10]. Malaysia has a substantial amount of hydropower resources and potential hydropower is estimated at 29,000 MW [11]. However, only around 2,091 MW off the 29,000 MW is utilized in 2008 [5]. This is basically due to the high capital investment required to develop the hydropower and often involves socio-economic issues. The development of a hydropower dam is overwhelmingly complex because the issues are not confined to the design, construction and operation of dams themselves but embraces the issues of social, environmental and political issues. Table 5 shows the installed capacity of major hydropower stations in Malaysia with a total capacity of 2,091 MW.

Sarawak has abundant hydropower potential with has a total capacity of 108 MW installed in 2009. Sarawak plans to increase hydropower capacity to 3500 MW by 2015 and 7723 MW by 2020,

Table 5
Installed capacity of major hydropower stations in Malaysia.

Station	Installed capacity (MW)	Total (MW)
1. Terengganu		
Stesen Janakuasa Sultan Mahmud Kenyir	4×100	400.0
2. Perak		
Stesen Janakuasa Temenggor	4×87	348.0
Stesen Janakuasa Bersia	3×24	72.0
Stesen Janakuasa Kenering	3×40	120.0
Chenderoh	$3 \times 10.7 + 1 \times 8.4$	40.5
Sg. Piah Hulu	2×7.3	14.6
Sg. Piah Hilir	2×27	54.0
3. Pahang		
Stesen Janakuasa Sultan Yussuf, Jor	4×25	100.0
Stesen Janakuasa Sultan Idris II, Woh	3×50	150.0
Cameron Highland Scheme		11.9
4. Kelantan		
Pergau	4×50	600.0
Kenerong Upper	2×6	12.0
Kenerong Lower	2×4	8.0
5. Sabah		
Tenom Pangi	3×22.0	66.0
6. Sarawak		
Batang Ai	4×23.5	94.0
Total		2,091.0

after that 20 GW by 2030 [12]. It has also announced plans to develop several large hydroelectric projects under the Sarawak Corridor of Renewable Energy (SCORE). Currently, the biggest hydropower project in Malaysia is the on-going Bakun hydropower project having a capacity of 2400 MW. Bakun dam in Sarawak is one of the largest dams in South-East Asia and it is emission free which has no impact on global warming [13]. It involves the construction of a 207 m high rock filled with concrete dam creating a reservoir nearly 70,000 ha, about the size of Singapore [14]. In the long term, there are plans to share resources with peninsular Malaysia, Brunei and Kalimantan (the Indonesian part of Borneo). The 2400 MW Bakun scheme is scheduled to begin operation in early 2011 and is followed by the 944 MW Murum scheme, 80 km upstream. The plan will reach 6000 MW of hydro installed capacity within 8 years [12]. The Murum dam is already identified to be developed, whereas feasibility studies are being conducted for the Baleh dam (950 MW) and Pelagus dam (770 MW) in the upper reaches of the Rejang river in Sarawak [15].

4. Renewable energy

Renewable energy includes energy derived from natural processes that do not involve the consumption of exhaustible resources such as fossil fuels and uranium. Solar, wind and mini hydropower, biomass and geothermal energy are the constituents of renewable energy. Apart from the main sources of energy like natural gas, oil, coal and hydropower, the government of Malaysia has always been looking and studying into other possible renewable energies to utilize. Despite high growth rates, renewable energy still represents only a small part of today's global energy picture. Therefore, this study will look into the aspect of renewable energy such as biomass, solar, wind and mini hydropower.

4.1. Biomass energy

Biomass is considered one of the renewable energy sources with the highest potential to contribute to the energy needs of modern society for both the industrialized and developing countries. Biomass energy contributes around 10–15% which is approximately 45 EJ of world energy use currently [16]. Biomass energy is an important source of energy in most Asian countries. Several countries in Asia have established targets for the use of fuels produced from biomass as an alternative renewable fuel such as Malaysia [17]. Biomass refers to any woody based material from plant that store energy through photosynthesis. Substantial amounts of fuel wood, agricultural crops and residues, empty fruit bunches, animal wastes and leaves are used by households and industries.

Biodiesel is the renewable energy mainly derived from vegetable oils or animal fats and has shown great potential to serve as a substitute to petroleum-derived diesel for compression ignition (CI) engine [18]. The world's total biodiesel production was around 1.8 billion liters in 2003 [19]. In European Nations (EU) alone, the demand for biodiesel is projected to increase from 3 million tons in 2005 to 10 million tons in 2010 [20]. Table 6 depicts the top 10 countries in terms of absolute biodiesel production potential with Malaysia far ahead among the rest [21]. The feedstock available for development of biodiesel in these nations are 28% for soybean oil, 22% for palm oil, 20% for animal fats, 11% for coconut oil, while rapeseed, sunflower and olive oils constitute 5% each [22]. Biodiesel status as a renewable energy source was further solidified in Malaysia when Envo Diesel had been introduced in 2006. Envo Diesel was a mixture of 5% blend of processed palm oil with 95% petroleum derived diesel. Malaysia's richness in oil palm is the primary driving force for its development of biodiesel industry. Therefore, Malaysia does not need to rely on foreign import for raw materials to develop its own biodiesel industry. Furthermore, using raw materials from own plantations will enable biodiesel developers to control the cost and quality of the biodiesel production more efficiently [23]. Hence, Malaysia is one of the countries which actively advocates for the commercial production and usage of biodiesel as fossil fuels replacement due to its rich oil palm resources.

Table 6
Top 10 countries in terms of absolute biodiesel production [21].

No.	Country	Volume (million liters)	Production cost ($/L)
1	Malaysia	14,540	$0.53
2	Indonesia	7,595	$0.49
3	Argentina	5,255	$0.62
4	USA	3,212	$0.70
5	Brazil	2,567	$0.62
6	Netherlands	2,496	$0.75
7	Germany	2,024	$0.79
8	Philippines	1,234	$0.53
9	Belgium	1,213	$0.78
10	Spain	1,073	$1.71

Average production cost per liter is calculated from all available lipid feedstock prices, increased by a $0.12 refining cost and decreased by $0.04 for the sale of by-products.

The total land area in Malaysia amounts to 32.90 million ha. The total land area under natural forest is 20.1 million ha (61%) and agriculture area is 4.89 million ha which is 14.9% of land area in Malaysia [24]. The major agricultural crops grown in Malaysia are rubber (39.67%), oil palm (34.56%), rice (12.68%), cocoa (6.75%) and coconut (6.34%). Malaysia is committed to sustainable development in minimizing CO_2 emissions and adopting sustainable agricultural practices that conserve the rainforests and wild life [25]. One of the major characteristics of the forestry and agricultural sector is the production of large quantities of processing residues which have no economic value. But the energy in solid wastes particularly biomass can be extracted either by direct combustion or by conversion into a more valuable and usable forms of energy.

Malaysia is one of the world's major producers of oil palm, where a total 4.5 million ha of land in Malaysia is under oil palm cultivation. It produced 17.73 million tons of palm oil and contributed about RM 65.19 billion to the Malaysia export in 2008. Malaysia accounts for 41% of world palm oil production and is the biggest palm oil exporter with 14.21 million metric tons which accounted for almost half of the total exportation of oil in the world [26]. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats in general. Malaysia has position herself in the right path to utilize biomass as a source of renewable energy and this can act as an example to other countries in the world that has huge biomass feedstock [27]. The current installed biodiesel production capacity is about 10.2 million tons in Malaysia [28]. There are many active biodiesel plants installed in year 2008 with a total annual biodiesel production capacity of 1.49 million tons as shown in Table 7 [29]. Besides, an additional four biodiesel plants with combined

Table 7
Active biodiesel plants in 2008 [29].

No.	Plant location	Number of plant	Plant capacity (ktons/year)
1	Pasir Gudang, Johor	4	630
2	Lahad Datu, Sabah	2	300
3	Kuantan, Pahang	1	200
4	Ipoh, Perak	1	200
5	Teluk Panglima Garang, Selangor	1	150
6	Setiawan, Perak	1	60

Table 8
Palm oil biomass components and potential energy generated [27,30].

Biomass component	Quantity (million tons)	Calorific value (kJ/kg)	Potential energy generated (Mtoe)
Empty fruit bunch	17.00	18,838	7.65
Mesocarp fiber	9.6	19,096	4.37
Shell	5.92	20,108	2.84
Palm kernel	2.11	18,900	0.95
Total	34.63		15.81

annual capacity of 190,000 tons are expected to commence commercial production by the end of 2009.

Presently million hectares of land in Malaysia is occupied with oil palm plantation generating huge quantities of biomass. In this context, biomass from palm oil industries appears to be a very promising alternative source of raw materials including renewable energy in Malaysia [27]. Being the largest palm oil producer in the world, Malaysia has approximately 362 palm oil mills, processing 71.3 million tons of fresh fruit bunch per year and producing an estimated 19 million tons of crop residue annually in the form of empty fruit bunch, fibre and shell [30]. Table 8 shows the calorific values and moisture content of these residues. Palm oil is one of the most efficient oil bearing crops in terms of land utilization, efficiency and productivity. A single ha produces up to 8 times more oil than other oilseeds. Oil yields from palm oil produces an average of 3.85 tons of oil/ha annual compared to rapeseed, sunflower seed and soybean as shown in Table 9 [29].

One of the ways to reduce the dependency on edible oil to make biodiesel is to use non-edible oils. Non-edible oils used for feedstock mostly are the oils with higher free fatty acids such as jatropha (*Jatropha curcas*), castor, karanja (*Pongamia pinnata*), rubber seed (*Ficus elastic*), sea mango and etc. Table 10 shows oil yield for major non-edible oil sources, including those that have been commercialized to produce biodiesel [31]. Jatropha in particular has an extra advantage over other oil sources because it is a drought-resistant plant capable of surviving in abandoned and fallowed agricultural land [32]. Therefore, the potential of using jatropha as a feedstock for biodiesel production has attracted much attention. Compared to palm oil biodiesel industry, biodiesel produced from jatropha is still in its nascent state in Malaysia [33].

Biodiesel blend fuel is available at many service stations across US and European countries. The world total biodiesel production is 11 million metric tons in 2008 and the total biodiesel production estimated can be as high as 20 million tons in 2010 [4]. Besides, Boeing air craft has started its research on using jet biofuel as a sustainable alternative to conventional fuel. This will increase the biodiesel demand substantially in the future. Therefore, biomass is one the potential source of renewable energy and the conversion of plant material into a suitable form of energy. Although the use of biomass as renewable energy resources has a lot of benefits, it faces numerous challenges. Firstly, ensuring sufficient continuous supply of biomass seems to be the biggest challenge of utilizing biomass in Malaysia. Secondly, the development of technology to convert the biomass energy resources into usable forms is still not that established. Although it was reported by several researches and studies, the commercialization of research findings has not been fully undertaken on a large scale [6]. These are among some of the practical issues that need to be addressed before the wider utilization of biomass energy can be expected in Malaysia.

Table 9
Average oil yield of major oil crops [29].

Crop	Oil yield (tons/ha/year)
Palm oil	3.85
Rapeseed	0.66
Sunflower	0.50
Soybean	0.45

Table 10
Oil yield for major non-edible oil resources [31].

Oil source	Oil yield (kg/ha/year)	Oil yield (wt%)
Jatropa	1590	Seed (35–40); Kernel (50–60)
Rubber seed	80–120	40–50
Castor	1188	53
Pongamia pinnata	225–250	30–40
Sea mango	N/A	54

4.2. Solar energy

Solar energy is the most promising source of clean, renewable energy and it has the greatest potential of any power source to solve the world's energy problems [34]. Although solar power producing devices have been around for over 50 years, solar electricity devices often referred to as photovoltaic (PV) are still considered as cutting edge technology. Globally, there are about 1700 TW of solar power are theoretically available over land for photovoltaic (PV). The capture of even 1% of this power would supply more than the world's power needs. Cumulative installed solar PV power at the end of 2007 was 8.7 GW, with less than 1 GW in the form of PV power stations and most of the rest on rooftops [35]. The capacity factor of solar PV ranges from 0.1 to 0.2, depending on location, cloudiness, panel tilt and efficiency of the panel. Current technology of PV capacity factors rarely exceed 0.2 based on calculations that account for many factors, including solar cell temperature, conversion losses and solar isolation [36]. Photovoltaic systems have a number of merits and unique advantages over conventional power-generating technologies. PV systems can be designed for a variety of applications and operational requirements, and can be used for either centralized or distributed power generation. Energy independence and environmental compatibility are two attractive features of PV systems. The fuel (sunlight) is free and no noise or pollution is created from operating PV systems. In general, PV systems that are well designed and properly installed require minimal maintenance and have long service lifetimes. However, at present, the high cost of PV modules and equipments are the primary limiting factor for the technology.

Solar power or also known as photovoltaic system is estimated to be four times the world fossil fuel resources in Malaysia [37]. The climatic conditions are favourable for the development of solar energy due to the abundant sunshine throughout the year. In Malaysia, the tropical environment has been characterized by heavy rainfall, constantly high temperature and relative humidity. The annual average daily solar irradiations for Malaysia are from 4.21 kWh/m^2 to 5.56 kWh/m^2 [38]. The highest solar radiation was estimated at 6.8 kWh/m^2 in August and November while the lowest was 0.61 kWh/m^2 in December. The Northern region and a few places in East Malaysia have the highest potential for solar energy application due to its high solar radiation throughout the year. A PV system consists of several solar cells that convert light energy into electricity. PV is an elegant means of producing electricity on site, directly from the sun without concern for fuel supply or environmental impact. Solar power is produced silently with minimum maintenance, no pollution and no depletion of resources. PV system is also exceedingly versatile and can be used to pump water, grind grain and provide communications and village electrification in situations where no electricity is available [6].

Currently, solar energy applications mostly oriented towards domestic hot water systems, water pumping, drying of agricultural produce. Most of the solar power used in Malaysia is on domestic

level only and large scale commercial use is not significant yet. It is estimated that there are more than 10,000 units of domestic hot system using PV system at the moment in Malaysia [39]. Although PV system has tremendous potential, especially for remote areas in Malaysia, the cost of PV panels and technology are extremely high for mass power generation. The current market value of PV system is about RM 28.00/Wp (US$ 8.40) [40]. Due to the high initial cost of PV system, Malaysia does not have any local PV manufacturer. All the PV modules and inverters are imported from foreign countries like Germany and Japan, hence causing the cost of PV systems to be very high. As a result, PV systems are not an attractive option to the public.

A 100 kWp demonstration photovoltaic project was implemented under the initiatives of the Ministry of Energy, Water and Communications in 1995 in Marak Parak, Sabah. This project has given the necessary beginning for the effective and efficient transfer of technology in the field of PV power generation in Malaysia [39]. In order to reduce the cost of PV system, the Malaysia has carried out a project named Malaysia Building Integrated Photovoltaic (MBIPV) in 2005. This project was funded by the government, Global Environment Facility disbursed through United Nations Development Programme (UNDP/GEF) and various private sectors [41].The principal objective of this project is to reduce the long-term cost of building integrated photovoltaic (BIPV) technology within the Malaysian market. The impact of the project subsequently leads to sustainable and widespread BIPV technology applications that avoid greenhouse gasses (GHG) emission from the electricity supply industry. Over the lifetime of the project, the energy generated will avoid 65,100 tons of CO_2 emissions from the country's power sector [42]. The project results are expected to induce an increase of BIPV application by 330% from the baseline in 2005. The full project addresses in an integrated manner the long-term cost reduction of the BIPV technology and adoption of supportive regulatory frameworks to establish the desired environment for a sustainable BIPV market [43]. After the BIPV programme is introduced in 2005, the cost of BIPV has dropped to RM19k/kWp with a cost reduction of 40% by the year 2010 as shown in Fig. 5.

Another national MBIPV programme, SURIA 1000, which is targeting the residential and commercial sector, will establish the new BIPV market. SURIA 1000 will provide direct opportunities to the public and industry to be involved in renewable energy and environmental protection initiatives. Since 2007, limited number of grid connected solar PV systems will be offered to the public on a bidding (auction) concept with the minimum BIPV capacity for bidding is 3 kWp per application. Successful bidders would then install the building integrated PV at their premises and costs of the PV systems would be borne by the successful bidders at the bidding price and supplemented by the project. This programme is co-financed by the public, Malaysia energy commission and the PV industry company. It is expected that PV players will finally offer BIPV system prices equivalent to Europe and Japan. Nowadays, the cost of a 5 kWp BIPV turn-key roof-top system in Malaysia is about RM27,000/kWp. Thus, a 5 kWp BIPV system is estimated to cost RM135,000. This will facilitate the creation of sustainable BIPV market upon the completion of the programme. The system will produce approximately 6,000 kWh of energy per annum [44].

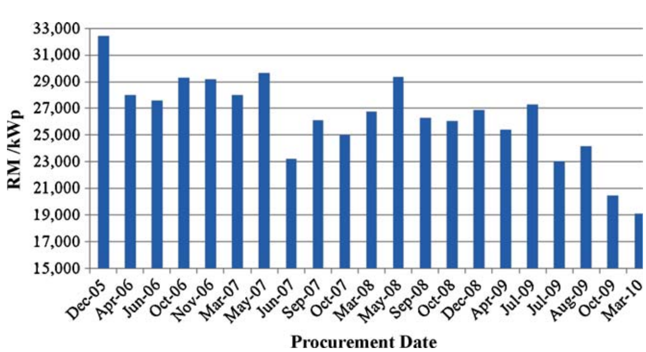

Fig. 5. Average BIPV price/kWp from 2005 to 2010 in Malaysia [41].

4.3. Wind energy

Wind power is the conversion of wind energy into a useful form of energy such as using wind turbines to make electricity, wind mills for mechanical power, wind pumps for pumping water or sails to propel ships [45]. At the end of 2009, worldwide wind powered generators capacity was 159.2 GW [46]. All wind turbines installed worldwide are generating 340 TWh per annum, which is about 2% of worldwide electricity usage. Wind power is growing rapidly and having doubled in the past three years. The US and China lead the growth of wind power capacity that accounted for 61.9% of the total additions to wind capacity in 2009 [47]. On the other hand, USA and China together represented 38.4% of the global wind capacity which is 61.1GW. However, the top five countries (USA, China, Germany, Spain and India) represented 72.9% of the worldwide wind capacity. Several European countries have achieved relatively high levels of wind power penetration such as 20% of stationary electricity production in Denmark, 15% in Spain and Portugal, 9% in Germany by the year 2009 [46].

Asia became the world's wind locomotive in the year 2009, mainly due to the two large markets of China and India. The total installed wind capacity in Asia reached 40.0 GW (25.1% of the global capacity). The continent had the second highest growth rate of all world regions which is 63.3% or 15.5 GW increased in 2009. In Malaysia, wind energy conversion is a serious consideration. The potential for wind energy generation in Malaysia depends on the availability of the wind resource that varies with location. Understanding the site-specific nature of wind is a crucial step in planning a wind energy project [48]. Detailed knowledge of wind on-site is needed to estimate the performance of a wind energy project. This first requires a general assessment of the wind energy potential nationwide [49].

In the early 1980s, Solar Energy Research Group from University Kebangsaan Malaysia (UKM) collected wind data from ten stations distributed all over Malaysia (six in Peninsular and four in East Malaysia, Sabah and Sarawak) for a 10-year period (1982–1991). The results show that stations located at Mersing and Kuala Terengganu has the greatest wind power potential in Malaysia [50–51]. Besides, the analysis indicates that applications involving small wind machines could be used to provide electricity on the relatively undeveloped East coast of Peninsular Malaysia and off-shore islands which are not connected to the national grid [50]. Apart from that, most recent research on potential wind energy in 2003 show that the annual offshore wind speed is around 1.2–4.1 m/s for Malaysian waters. The highest potential is in the east peninsular Malaysia with annual vector resultant wind speed of 4.1 m/s [52].

In 2005, a 150 kW wind turbine in the Terumbu Layang Layang demonstrated with some success [53]. However, the availability of wind resource varies with location. Detailed knowledge of the wind at a site is needed to estimate the performance of a wind energy project. Wind energy conversion systems have great potential in tourist resort islands. Various institutions of higher learning and research institutions like UKM and UTM have conducted research and development in the field of wind energy. In recent year, TNB has installed 2 units of wind turbine (2×100 kw) in Pulau Perhentian for energy generation. Besides, Ministry of rural and regional development also had installed 8 units of small wind turbine (5–10 kw) in Sabah & Sarawak for community [54].

Wind energy is considered a green power technology due to it has only minor impacts on the environment. Wind energy plants produce no air pollutants or greenhouse gases. Funding for research and development in this field of renewable energy should be allocated with the objectives of solving fundamental problems and product development.

4.4. Mini hydro (small scale hydro) energy

Worldwide mini hydropower or small-scale hydropower projects have become more popular because of their low cost, reliability and environmental friendliness. The definition of a small hydro project varies but a generating capacity of up to 10 megawatts (MW) is generally accepted as the upper limit of what can be termed small hydro. In 2008, mini hydropower installations grew by 28% over year 2005 to raise the total world small hydro capacity to 85 GW [55]. There are over 70% of mini hydro in China (65 GW), followed by Japan (3.5 GW), the United States (3 GW) and India (2 GW). China plans to electrify a further 10,000 villages by 2010 under their China Village Electrification Program using renewable energy, including further investments in small hydro and photovoltaics [55].

Malaysia has carried out a few studies on its small-scale hydropower resources as a result of which it has been concluded that mini hydropower projects will be economically viable if combined with the additional benefits of flood and irrigation control as well as encouraging tourism. There are 26 approved applications of mini hydro project under small renewable energy power (SREP) with total 101.9 MW generation capacity and 97.4 MW grid connected capacity [56]. In Malaysia there are about 500 MW potential mini hydropower but only 29 MW was utilized in power station in 2008 [57]. The installed capacity of mini hydropower stations were mainly in Sabah and Sarawak with total capacity 8.3 MW and 7.3 MW respectively as show in Table 11 [4].

In 2002, the installation of a mini hydropower system in Long Lawen under the Berneo project provided the village with a cost-effective, clean and reliable electricity system maintained by the community [58]. The 10 kW mini hydropower system is self-financing and eliminates 1,000 gallons of diesel fuel per year. The Natural Resources and Environment Ministry is looking into creating micro-hydro electric systems at remote villages in Sabah and Sarawak that are too far from the main electricity grid to receive power supply [59]. It was a good alternative source of power for villages that would otherwise have to depend on diesel powered generators. The system is cheap and pollution free, where five mini hydropower systems are already operational at villages in Sabah and Sarawak. Bario Asal village is one of the villages installed with mini hydropower, residents of Bario Asal longhouse depend on the Pa Merario River supply water for domestic purposes and agriculture [60]. On the other hand, mini hydro-electric power plants convert the energy of flowing water into electricity and producing 10 kW of electricity.

In 2010, Tenaga Nasional Berhad (TNB) is aiming to complete the rehabilitation of 26 mini hydropower plants by mid 2011 and possibly expanding the capacity of some of the plants. The total capacity of the 26 mini hydro plants is 12.3 MW and it will be operational in phases from now until the middle of 2011. While it is costly to develop hydro plants, the current high price of coal and potentially higher gas prices in future would make hydro projects more viable. The targeted installed capacity for mini hydro is 490 MW by 2020 under the Malaysian government's blueprint to develop renewable energy sources [61].

Table 11
Installed capacity of mini hydropower stations [4].

State	Total
Kedah	1.56
Perak	3.21
Pahang	3.50
Kelantan	3.16
Terengganu	1.94
Sabah	8.33
Sarawak	7.30
Total	29.00

5. Conclusion

Malaysia energy sector is still heavily dependent on non-renewable fuel such as crude oil, natural gas and coal as a source of energy. Economical growth in Malaysia depends on the energy consumption; the increase in energy consumption is expected to be in uptrend around 6–8% annually based on nation economic growth. These non-renewable fuels are gradually depleting and contribute huge amount of greenhouse gas emission.

Malaysia is not ready to embrace and displace non-renewable energy with renewable energy in near the future. The implementation of various policies and programs by the government of Malaysia has increased the awareness of the importance of the role of renewable energy in a sustainable energy system. Malaysia has the potential to be one of the major contributors of renewable energy in the world via palm oil biomass. Subsequently, Malaysia can then become a role model to other countries in the world that has huge biomass feedstock.

Despite the continuous effort to improve on renewable energy, they are not yet utilized to their maximum potential in Malaysia. Government, non-government agencies and the public will have to take a more proactive step to promote and use renewable resources energy to increase a wider utilization of renewable energy in Malaysia. As a final note, to make the fuel mix for 2020 secure and environmentally sustainable, Malaysia must strive to increase its efforts in attaining greater efficiency in energy conversion, transmission and utilization.

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